Nano-Structured Solar Cells

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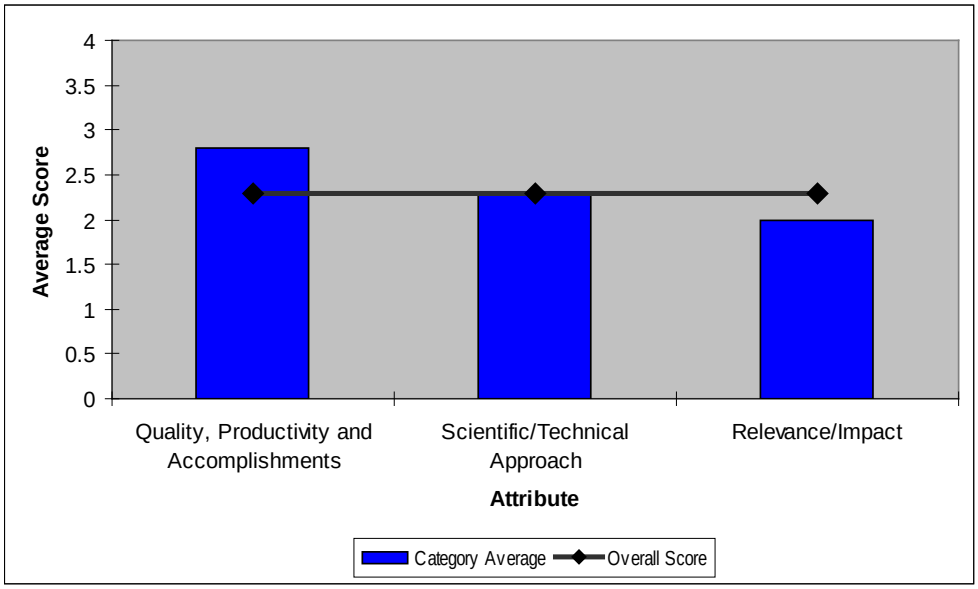

Goals and objectives of this project include work with polymer-carbon and nanotube composites, synthesized by in-situ polymerization; characterize composites for structural, thermal, optical, and electrical properties; dispersion of MWNTs in P3HT polymer matrix, etc.

Quality, Productivity and Accomplishments (Average Rating 2.8)

Rating	Comments
4.0	Little Rock Arkansas team developing CNT composites for OPV configurations and GaN nanowire devices. Good range of expertise, multidisciplinary group. Long publication list- 22 peer-reviewed papers and 11 conference papers last year related to this funding.
2.0	The quality of resources is good, but the level of productivity is fair.
2.0	The resources at Arkansas are more than adequate. The team is very capable and can realize the stated goals. The results have shown that there is a chemical interaction between carbon nanotubes and P3HT. Solar panels based on carbon nanotube/P3HT organic materials were disappointingly low. Goals have been set to increase the efficiency. Some very preliminary results based on Si were given but their value/reproducibility was not clear.
3.0	Very active research group with high productivity in terms of publications and presentation. Good progress in basic understanding of CNT for PV use.
3.0	"Research team seems qualified – PI has experience in CNTs, co-PIs have polymer (particularly conducting systems), nanocomposites, and device architecture. Reasonable equipment for conducting research – limited XPS and work function access. Systems studied focused on SWNTS in P3HT with an attempt to understand the loading ability of the SWNTs. Have tried to improve loading using in-situ polymerization. Claiming at low SWNT concentrations there is a strong interaction between the P3HT and the SWNT – with the polymers adopting a thin layer in the surface – what is thermodynamic driving force to extend the polymer chain?"

Scientific/Technical Approach (Average Rating 2.3)

Rating	Comments
3.0	While much work was done and presented, the overall strategy is confusing. Many different topics, hard to see why each is being pursued. They are approaching some critical fundamental issues (learning about transport phenomena with T-dependence measurement technique) and synthesizing novel composite materials.
2.0	There are 3-4 very different foci for the project. It would be more productive to narrow the scope of the project to either CNT/P3HT composite active materials, or graphite composites for electrode materials, or GaN nanorod cells, but not all three (and I would recommend eliminating the airbrushed CNT on Si part of the work).
1.5	The approach was not adequately described in the presentation, but became more clear after some discussion. Carbon nanotube-based p-n solar cells and carbon nanotubes with organic PVs is a sound approach that may yield inexpensive PVs. It was asserted that carbon nanotubes would enhance the efficiency and stability of Si and III-V solar cells. It is not at all clear that this is true. Using expensive PV materials with organics takes away the big potential advantages of organic PVs: low temperature scalable processing of inexpensive PV materials.
3.0	Approach reflects academic research on system with many unknowns. Evaluation of CNTs is important because of the significant differences in quality from different suppliers. Study of interaction between polymer and CNT by NRM may yield some basic understanding of efficient carrier transport. Single walled CNTs reach highest cell efficiencies. Basic understanding needed. What are the limitations?
2.0	"The in-situ polymerization work needs further expansion – what is the mechanism of polymerization and the effect of surface groups on the SWNTs on the polymerization? Efficiency of the system originally was very poor – was improved using PCBM and higher concentrations of SWNTs. Future work to focus on thickness of the active layer and further work on the concentration of the SWNT composites. What is the driving force for the polymer chains to enter the graphite layers? – looking at using the graphite composites as electrodes for device fabrication. Have also looked at SWNT with n-Si for PV devices. Air brushed SWNT on silicon wafer – seemed like very thick films. Enhanced PV device by using thionyl chloride treatment of SWNT – got about 4.5% efficiency. How does this relate to the interaction of the SWNT with the silicon? Roughness of SWNT films? Use no polymer which states as an advantage to improve the stability. I was confused with the graphite discussion of the polymer migrating between the graphite layers - this is highly unlikely due to the required change in random coil size and the associated energy penalty."

Relevance/Impact (Average Rating 2.0)

Rating	Comments
2.0	One topic is development of CNT composites based on a photoactive layer (thiophene) P3HT:CNT- needed good dispersion, so did in situ polymerization of CNTs with FeCl3 catalyst in monomer. Looking at doping CNTs w/ B and N to change work function. Strong interactions between pi electrons of P3HT and CNTs. Temperature dependence of composites conductivity considering metallic, fluctuation assisted and variable range hopping transport. Efficiency is about 0.1%, ascribed to difficulty in dissociating the excitons, addition of PCBM helps. Looking at ways to length sort CNTs and choose ideal length and avoid short circuit problem. Also added fullerenes and saw improvements. Graphite/PANI composite exhibits higher conductivity than graphite. Find the transport mechanism is different than that of graphite (T dep). Made device with SWNTs 100nm sprayed on n-type Si, and NTs are thought to be p-type and can be made more p-type by doping (future work). Looking at chirality of CNTs and how it affects properties. Ideally, CNT should be semiconducting. Looking at a device based on p-type and n-type CNTs with a junction. Little discussion in presentation about GaN nanowire device, but shown in summary writeup. Fabrication effort is underway, but testing and performance not shown.
2.0	Work in either of these three main areas could produce useful data, but the team is too small with limited resources to make real progress in all three at once. Even a project focused solely on producing better CNT dispersions would build on the studies they have done already and yield useful information.
2.0	One has to believe that organic PVs have a future to think that this research will have a influence on practical solar cells. I do believe that they will and therefore found some merit to the fundamental studies of carbon nanotube-polythiophene interactions. The activities described will not influence technical barriers in Si or III-V type materials.
2.0	At the present level, how much efficiency CNTs can reach. This project is focused on answering some basic questions. Some findings are not very encouraging. Strategies on how to overcome barriers need to be developed.
2.0	"Impact is difficult to establish due to the uncertain nature of many of the results. It is difficult to see where there will be an expansion of the fundamental understanding of the PV devices performance – particularly in the polymer/SWNT systems. The driving force for uncoiling of the polymer should be the same regardless of the bundling and there should be more consideration of the surface initiated possibilities to improve the surface coverage – particularly at the high concentrations of the SWNTs. The CNT spray film is a little confusing and it was difficult to gain an understanding of exactly what is the mechanism of improvement. The polymerization study for modification of the CNTs really needed more focus to understand how the concentration of CNT affects the polymerization mechanism. Maybe should have looked at polymers that have little interaction with the CNTs, also would be good to know actual thickness of the polymer on the surface of the CNT to gain an understanding of the structure of the polymer/CNT interface."

Overall (Average Rating 2.3)

Rating	Comments
3.0	Somewhat scattered and confusing research plan, but with many elements. Would be strengthened with a one-page document describing why each of the tasks is being pursued and prioritizing the efforts. Possible down-selection of tasks that do not look as promising as others. CNT composites are interesting, encourage them to better express their work in context with current state-of-the art, both in conventional technologies and in related efforts. For example, how does the CNT composite improve (or seek to improve) the performance of OPVs? Why is a GaN nanowire structure preferred over thin film geometry?
2.0	The projects need to be narrowed in scope, or reduced in number in order to make substantial progress in a reasonable amount of time.
1.5	This was a very poor presentation that suggests the research is not directed. Many ideas/concepts were loosely described. For example, the PI mentioned using GaAs in the future but the possible benefits of this were not described. The obvious problems that would be associated with this were not discussed. To coat nanotubes on such materials and state that they are among the most efficient 'ORGANIC" solar cells borders on dishonesty. At one extreme, one could deposit a thin organic layer on Martin Green's high efficiency PVs and provided that the organic does not absorb too much light, set all kinds of records. If the longer term (more basic) research contributions in organic-carbon nanotubes are considered there is some possible impact of this research. The only means by which success will be realized in this research project is serendipity. The project should probably be terminated.
3.0	[none]
2.0	Overall this was a fair project that contained some interesting elements but significant questions regarding approach and impact of the project (see above). While three different projects were outlined as part of this study, there were major questions raised with each and I felt that none of the projects had been studied in significant detail to provide a thorough understand of the fundamentals so as to lead to significantly improved device performance.